Analysis of the Potential of Refuse Derived Fuel (RDF) Technology as a Waste Management Solution in Medan City

Abstract

Waste management in Medan City faces significant challenges due to the increasing volume of waste generated each year. One proposed solution to this problem is the implementation of Refuse Derived Fuel (RDF) technology, which aims to convert waste into an alternative fuel source. This study aims to analyze the potential of RDF technology as a waste management solution in Medan City and identify strategies for its development. The research employs a qualitative descriptive approach with primary and secondary data collection. Primary data were obtained through interviews with relevant stakeholders, while secondary data were gathered from reports, publications, and relevant literature. The results indicate that the application of RDF technology in Medan City holds great potential for reducing waste volume at the Final Disposal Site (FDS), lowering carbon emissions, and creating new employment opportunities. However, the implementation of RDF technology also faces several challenges, such as high initial investment costs, inadequate infrastructure, and low public awareness regarding waste segregation. A SWOT analysis reveals that the main strengths for developing RDF in Medan City lie in the abundant availability of waste as raw material, government policy support, and opportunities for partnerships with the private sector. Conversely, key weaknesses include the variability in waste quality and the high cost of acquiring technology. This study concludes that the development of RDF in Medan City has promising prospects, particularly if supported by government policies, strengthened infrastructure, and synergy with the private sector. The implementation of appropriate strategies could position RDF as an effective waste management solution, supporting sustainable development and clean energy transition in Medan City. By adopting RDF technology, Medan City can reduce dependence on fossil fuels, extend the lifespan of its landfill, and create broader economic, social, and environmental benefits.

Keywords: Final Disposal Site, Medan, SWOT, Refuse Derived Fuel, Economy

I. Introduction

Rapid population growth and increasing urbanization have a significant impact on waste volume, particularly in urban areas (Santoso & Wahyuni, 2021; Sari et al., 2022). Medan City, as one of Indonesia's major cities, faces considerable challenges in waste management. Currently, Medan City generates approximately 2,000 tons of waste per day, of which only 13% is sorted and managed, while the remainder ends up in the Terjun Final Disposal Site (FDS) (Environmental Agency of Medan City, 2023). This situation places enormous pressure on the capacity of the Terjun FDS, which is increasingly limited, creating

an urgency to find effective and sustainable waste management solutions (Putri et al., 2022).

Poor waste management can trigger various environmental problems, ranging from soil, water, and air pollution to increased greenhouse gas emissions, especially methane from landfills (Hardiansyah & Ramadhani, 2021). In the context of regional development, ineffective waste management can disrupt sustainable development and reduce the area's carrying capacity (Widodo & Santosa, 2020). Therefore, an innovative technology-based waste management strategy is required to address this challenge. One technology that is currently gaining attention is Refuse Derived Fuel (RDF), which enables the conversion of waste into an alternative fuel source (Chaerul & Wardhani, 2020).

RDF technology is a strategic solution for waste management as it can reduce the volume of waste disposed of in landfills while adding value by producing renewable energy (Mujayyin, 2020). RDF is produced from waste that is mechanically and biologically processed to generate fuel that can be used in various industries, such as cement factories and power plants (Nurhaliza, 2021). RDF has a relatively high calorific value, approximately 15-23 MJ/kg, making it a potential alternative to fossil fuels (Bimantara, 2012). The implementation of RDF has been carried out in several regions in Indonesia, such as Cilacap and Bali, with results showing a significant reduction in the volume of waste ending up in landfills (Nasyton, 2019).

Medan City has only one active landfill, the Terjun FDS, located in Terjun Village, Medan Marelan District. The capacity of the Terjun FDS is becoming increasingly limited, while the potential for waste generation continues to rise each year. The volume of waste accumulated at the Terjun FDS in 2023 reached over 719,103 tons, consisting of both active and passive piles (Environmental Agency of Medan City, 2023). Without immediate innovation in waste management, Medan City will face a serious waste management crisis, including environmental pollution and a shortage of landfill space (Putri et al., 2022).

To address this issue, Presidential Regulation No. 35 of 2018 encourages the development of waste management technologies based on RDF. This regulation aims to accelerate the construction of energy-based waste management infrastructure, including RDF facilities (Chaerul & Wardhani, 2020). The implementation of RDF in Cilacap has proven that this technology can reduce waste volume at the landfill by up to 86%, as well as create cost efficiencies in waste management (Nasyton, 2019). Therefore, Medan City has significant potential to adopt this technology as an effective waste management solution.

Refuse Derived Fuel (RDF) is produced through the conversion of solid waste, such as plastics, paper, and organic waste, into an alternative fuel. RDF has been applied in several cement factories, where it can replace up to 20% of coal as fuel (Mujayyin, 2020). In addition, RDF can be used in co-firing power plants, where RDF is utilized alongside coal to generate electricity (Nurhaliza, 2021). The use of RDF in power plants has been shown to reduce greenhouse gas emissions, particularly methane, which has a higher global warming potential than carbon dioxide (Bimantara, 2012).

The implementation of RDF in Medan City faces several challenges, including limited infrastructure and the need for significant investment. Additionally, resistance from local communities to the development of waste management facilities often arises due to the "Not In My Backyard" (NIMBY) phenomenon (Chaerul & Wardhani, 2020). Therefore, public awareness and education, as well as support from local government policies, are essential to ensure the successful development of RDF facilities. Collaboration between government, the private

sector, and the community is needed to ensure the sustainability of RDF implementation in Medan City (Widodo & Santosa, 2020).

Based on these issues, this study aims to analyze the potential for developing Refuse Derived Fuel (RDF) technology as a waste management solution in Medan City. The research also seeks to explore the opportunities and challenges faced in RDF implementation, including the analysis of economic, social, and technical factors (Mujayyin, 2020; Chaerul & Wardhani, 2020). With this research, it is expected that waste management in Medan City can become more effective, efficient, and environmentally friendly, supporting the development of a circular economy-based waste management approach.

Based on the aforementioned background, this research adopts the topic "Analysis of the Potential of Refuse Derived Fuel (RDF) Technology as a Waste Management Solution in Medan City." By analyzing the potential of RDF in Medan City, it is hoped that strategic solutions and data-driven policies can be formulated to accelerate the development of RDF in the city. This research not only aims to address waste management issues but also promotes environmentally friendly waste management and creates new economic value through the concept of waste-to-energy.

II. Methods

This study was conducted at the Terjun Final Disposal Site (FDS) in Terjun Village, Medan Marelan District, Medan City, covering an area of approximately ±16 hectares. The research was carried out from August to November 2024 using a qualitative descriptive approach to provide a clear and structured analysis of the research results. This approach facilitates a comprehensive understanding of the findings by utilizing narratives, tables, graphs, and simple diagrams. The data analysis focuses on real conditions observed at the site, using empirical methods to address the research objectives.

The study utilizes both primary and secondary data. Primary data were collected directly from the field through observations, interviews, and documentation. This includes information on the conditions of the Terjun FDS, waste processing procedures, and the potential for RDF (Refuse Derived Fuel) technology implementation. Secondary data were gathered from pre-existing sources, such as journals, books, research reports, and official documents from government agencies, particularly the Environmental Agency of Medan City. These secondary sources support and supplement the primary data collected.

Data collection techniques employed include observation, interviews, document analysis, and literature review. Observations involve monitoring waste management processes at the Terjun FDS, including waste reception, sorting, and processing with RDF technology. Interviews are conducted with key informants, such as officials from the Environmental Agency of Medan City, FDS operators, waste management experts, and local community members. Document analysis includes the review of official reports, previous research, and policies related to waste management in Medan City. The literature review involves examining books, journals, and scientific sources relevant to waste management and RDF technology.

The informants in this study are selected based on their relevance to the research topic. They include representatives from the Environmental Agency of Medan City, the Regional Development Planning Board (Bappeda) of Medan City, environmental and waste management experts, technical specialists in RDF technology, private sector stakeholders, NGOs, and community members living near the Terjun FDS. A purposive sampling method was applied to select informants with specific knowledge of RDF development and its application in

Medan City. This selection provides a comprehensive perspective on RDF development, ensuring a holistic approach to the research.

Data analysis is conducted using a qualitative descriptive method. Information collected from observations, interviews, and document reviews is processed and presented in the form of narratives, tables, and graphs. The analysis uses a SWOT (Strengths, Weaknesses, Opportunities, Threats) framework to assess the internal and external factors influencing RDF development in Medan City. The analysis utilizes the Internal Factor Analysis Summary (IFAS) matrix and the External Factor Analysis Summary (EFAS) matrix to categorize key strengths, weaknesses, opportunities, and threats. The SWOT matrix is then used to formulate four development strategies: (1) **SO Strategy**: Leverage strengths to seize opportunities; (2) **ST Strategy**: Leverage strengths to mitigate threats; (3) **WO Strategy**: Address weaknesses to seize opportunities; and (4) **WT Strategy**: Address weaknesses to mitigate threats. This approach allows for the creation of evidence-based strategies for RDF-based waste management in Medan City.

III. Result and Discussions

The results of this study reveal that the Medan City Government has initiated the implementation of Refuse Derived Fuel (RDF) technology in collaboration with the Pangkalan Susu Steam Power Plant (PLTU). This initiative aims to reduce waste generation and achieve co-firing targets to decrease reliance on coal usage. The implementation of RDF in Medan City is still in its developmental phase, with waste processing and production of RDF fuel dependent on the technology and facilities provided by PLTU Pangkalan Susu.

Table 1. BBJP Production Results at Terjun FDS

No	Month		Production Quantity (Kg)	Total Production (Kg) Sent to PLTU
1	October	2022	765	765
2	November		1,703	2,468
3	December		2,621	5,089
4	January	2023	3,749	8,838
5	February		3,627	12,465
6	March		2,240	14,705
7	April		1,465	16,170
8	May		16,207	32,377
9	June		16,240	48,617
10	July		16,080	64,697
11	August		16,030	80,727
12	September		16,200	96,927
13	October		16,200	113,127
14	November		16,800	129,927
15	December		16,800	**146,727**

Source: Environtmental Office, 2023.

Since October 2022, the Terjun Final Disposal Site (FDS) has produced Solid Recovered Fuel (BBJP) from waste. Production capacity increased gradually from 765 kg in October 2022 to 16,800 kg in December 2023, with a cumulative total of 146,727 kg sent to PLTU Pangkalan Susu. This increase in production was achieved through the operation of organic waste shredders, initially producing an average of 2 tons per month with 4 workers, and later stabilizing at 16 tons per month with 12 workers. The production of BBJP significantly contributes to waste reduction, with daily waste reduction surpassing 1 ton per day.

Image 1. Terjun Final Disposal Site

Although the production of BBJP at the Terjun FDS is still far from the co-firing target of 120 tons per day, RDF implementation has made a tangible impact on waste management. The Medan City Government has assumed full control of the BBJP production equipment, which was previously managed by PLTU Pangkalan Susu. As the Terjun FDS nears its capacity limit, the city government has been compelled to find more effective waste management solutions. RDF is considered a strategic and viable alternative in this context.

Image 2. BBJP Production Equipment at Terjun FDS

However, the implementation of RDF technology in Medan City faces several challenges, including limited infrastructure, incomplete regulatory frameworks, and low public awareness regarding waste segregation. Moreover, Medan City has yet to establish specific regulations governing RDF handling and implementation. Nevertheless, existing waste management policies, such as Medan Mayor Regulation No. 26 of 2019, provide a basis for supporting RDF development.

From the perspective of spatial planning theory, RDF implementation in Medan City aligns with the theory of strategic facility placement. Placing RDF facilities near waste sources and industrial users, such as cement factories, enhances logistical efficiency. Sustainable development theory also supports RDF as a solution that integrates economic, social, and environmental aspects. RDF transforms waste into a valuable resource, reflecting the principles of a circular economy.

Experience from other regions shows that RDF can be an effective waste management solution. In Cilacap, Central Java, RDF has been used to replace coal in cement factories, reducing landfill waste by 30% and producing high-quality fuel. In Surabaya, RDF has helped reduce household waste while creating employment opportunities through community participation. These experiences offer valuable insights for Medan City, which can strengthen its RDF infrastructure, enhance public awareness, and foster partnerships with the private sector.

The adoption of RDF technology in Medan City presents significant potential for supporting waste management and regional development. From an environmental perspective, RDF reduces the volume of waste sent to landfills, thereby extending landfill lifespan and producing cleaner fuel alternatives compared to fossil fuels. From an economic perspective, RDF reduces overall waste management costs, generates economic value from waste, creates new jobs, and attracts renewable energy investors. From a social perspective, RDF increases public awareness of improved waste

management practices and enhances the quality of life for communities near landfill sites.

The development of RDF in Medan City is influenced by internal and external factors. Internal factors include the availability of infrastructure and technology, local government policy support, human resource capacity, community participation, and budget availability. External factors include market demand for RDF, national policies on waste management and renewable energy, technological advances, partnerships with external stakeholders, and public awareness. While these factors provide significant opportunities for RDF development, several threats, such as regulatory uncertainty, public resistance, and high infrastructure investment risks, must be addressed.

Analysis of RDF Development Strategies in Medan City

The development of Refuse Derived Fuel (RDF) strategies in Medan City is guided by a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. This approach aims to evaluate internal and external conditions, identify potential and challenges, and formulate strategic actions required for RDF development.

1. **Strengths**

- **Waste Volume Reduction**: RDF significantly reduces the amount of waste sent to landfills, extending the landfill's lifespan and decreasing waste management burdens.
- **Energy Production**: RDF converts waste into alternative fuel, which can be utilized in power plants and cement factories, reducing reliance on fossil fuels.
- **Carbon Emissions Reduction**: The use of RDF as an alternative fuel reduces greenhouse gas emissions compared to direct burning or unmanaged waste disposal.
- **Job Creation Potential**: RDF technology creates new employment opportunities in waste management and renewable energy production.
- **Cost Efficiency**: By converting waste into RDF, waste management costs are reduced, while generating new economic value.

2. **Weaknesses**

- **High Initial Investment**: RDF technology requires significant upfront investment to establish processing infrastructure.
- **Waste Quality Variability**: Not all waste types can be processed into RDF, making sorting and processing more challenging.
- **Limited Infrastructure**: Modern waste processing infrastructure is essential to ensure efficient RDF production.

- **Low Public Awareness**: Insufficient understanding of RDF and waste segregation among the public hinders effective waste management.
- **Dependency on Expertise**: RDF technology requires skilled personnel for its management and operation.

3. **Opportunities**

- **Government Policy Support**: National policies promoting renewable energy and waste-to-energy initiatives support RDF development.
- **Public-Private Partnerships**: Collaborations with private companies offer new investment and operational opportunities.

4. **Threats**

- **Regulatory Uncertainty**: Inconsistent regulations on RDF management hinder implementation.
- **Public Resistance**: Public opposition to RDF facilities may arise due to perceived environmental risks.

The SWOT matrix demonstrates the potential for optimizing RDF development in Medan City through partnerships, education, and investment in sustainable infrastructure. .

Table 2. Internal and External Strategy Factor Matrix (IFAS and EFAS)

Internal Factors

Strengths

No	**Strength**	**Weight**	**Rating**	**Score**
1	Reduction in landfill waste volume	0.30	3.75	1.13
2	Energy production from waste (alternative fuel)	0.20	3.75	0.75
3	Contribution to carbon emission reduction	0.15	3.625	0.54
4	Potential for job creation	0.20	3.75	0.75
5	Cost efficiency in waste management	0.15	3.5	0.53
Total Strength	**1**		**3.7**	

Weaknesses

No	Weakness	Weight	Rating	Score
1	High initial investment cost	0.25	3.125	0.78

2	Variability in waste quality	0.25	3.125	0.78
3	Insufficient modern waste management infrastructure	0.20	3.25	0.65
4	Low public awareness of RDF technology	0.15	3.375	0.50
5	Dependence on technology and skilled labor	0.15	3.375	0.50
Total Weakness	**1**		**3.21**	

External Factors

Opportunities

No	Opportunity	Weight	Rating	Score
1	Government support for renewable energy and waste management	0.20	3.5	0.70
2	Potential partnerships with the private sector and industry	0.25	3.625	0.90
3	Opportunities for international funding for green projects	0.20	3.5	0.70
4	Increasing public awareness of environmental issues	0.15	3.625	0.54
5	Reduction in energy costs through RDF usage as an alternative fuel	0.20	3.5	0.70
Total Opportunities	**1**		**3.54**	

Threats

No	Threat	Weight	Rating	Score
1	Regulatory instability in RDF management	0.20	3.5	0.70
2	Community opposition to RDF facilities	0.10	2.25	0.23
3	Competition with alternative waste management technologies (incinerators, landfill gas)	0.15	2.75	0.41
4	Fluctuations in fossil fuel prices	0.25	3.125	0.78
5	High initial investment risk for RDF infrastructure	0.30	3.5	1.05
Total Threats	**1**		**3.17**	

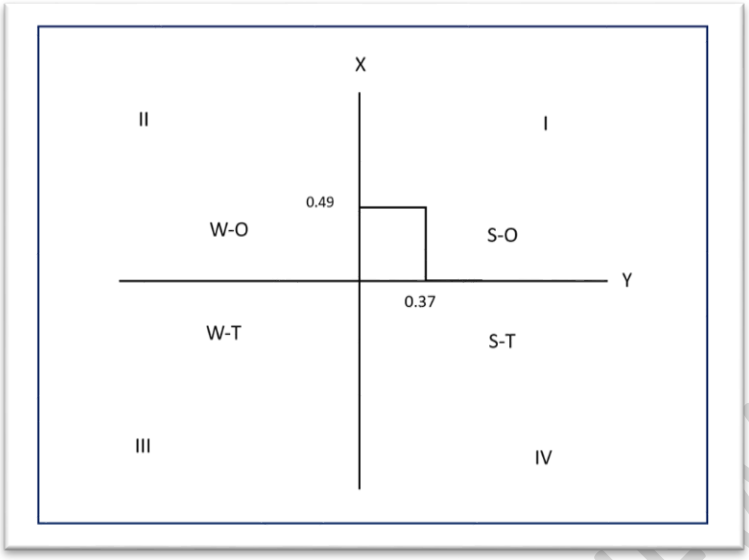

Image 3. SWOT Analysis Quadrant for RDF Development in Medan City

The SWOT matrix indicates that RDF development in Medan City can be optimized by leveraging its strengths and opportunities, such as the availability of waste raw materials, support from the industrial sector, and advances in waste processing technology. By capitalizing on these potentials, the Medan City Government can address its weaknesses, such as inadequate infrastructure and low public awareness. One strategic approach is to foster partnerships with the private sector and strengthen public education programs to increase community participation in waste separation initiatives.

The strategies derived from this SWOT matrix aim to mitigate external threats, such as competition from fossil fuels and regulatory uncertainties. This can be achieved by enhancing the quality standards of RDF and offering incentives to industries adopting RDF as an alternative fuel. These efforts not only support the resolution of waste management issues in Medan City but also promote the transition towards more sustainable energy management.

Development of Refuse Derived Fuel (RDF) Technology in Medan City

The development of RDF technology in Medan City is a strategic initiative that addresses waste management challenges while simultaneously providing an alternative energy source. RDF is a fuel produced from processed municipal solid waste that meets industry-specific energy requirements. This approach offers dual benefits: reducing waste in landfills and decreasing reliance on fossil fuels.

Based on the research findings, several RDF development strategies in Medan City have been formulated. The **SO (Strength-Opportunities)**

Strategy seeks to utilize the abundant supply of waste raw materials to attract local industries to use RDF as an alternative fuel. The **WO (Weakness-Opportunities) Strategy** emphasizes overcoming infrastructure deficiencies by leveraging opportunities from national policies and fostering public-private partnerships. The **ST (Strength-Threats) Strategy** aims to reduce pressure on the Terjun landfill by constructing eco-friendly waste processing facilities, thereby addressing community resistance. Finally, the **WT (Weakness-Threats) Strategy** underscores the importance of increasing public awareness through education and waste separation campaigns to minimize community opposition to RDF facilities.

These strategies align with the principles of sustainable development, which stress the importance of collaboration between the government, community, and private sector. Previous research by Nasyton (2019) in Cilacap highlighted the significance of synergy between the government and private sector in the successful implementation of RDF as a waste management solution. This collaboration can ensure the sustainability of RDF-based waste management systems and strengthen Medan City's position as a pioneer in renewable energy-based waste management.

IV. Conclusion and Recommendations

The implementation of Refuse Derived Fuel (RDF) technology in Medan City remains suboptimal. This is primarily due to the limited capacity of RDF machinery, which is still unable to meet market demand, thereby reducing its impact on waste management. However, RDF holds significant potential as an alternative waste management approach, a renewable energy source, and an economic opportunity. This potential aligns with the principles of a circular economy, which aims to transform waste into valuable economic resources.

The adoption of RDF in Medan City is influenced by both internal and external factors. Internal factors include the readiness of infrastructure, the quality of human resources, and the availability of technology. External factors encompass government policy support, regulatory frameworks, partnerships with the private sector, and public awareness of waste segregation. Collaboration between the government and private sector is a key element for accelerating RDF implementation in Medan City. The SWOT analysis reveals that RDF development is positioned in Quadrant I, indicating that the development strategy should focus on leveraging internal strengths to seize external opportunities.

To optimize RDF management in Medan City, it is recommended that the government continues to develop RDF technology by maximizing its strengths and opportunities. Supportive policies from the local government are crucial to strengthening RDF development. These include the establishment of clear regulations, enhancement of legal frameworks, and provision of incentives to the private sector for adopting RDF. Additionally,

the Medan City Government should build modern RDF processing facilities, strengthen the capacity of human resources, and increase public awareness through educational campaigns and waste segregation initiatives.

As a strategic measure, it is suggested that the Medan City Government capitalize on the abundant availability of waste and strengthen partnerships with local industries. Collaborations with RDF-consuming industries, such as cement factories and power plants, should be intensified to create a stable RDF market. With the right strategy, RDF-based waste management in Medan City could become a national model for renewable energy-based waste management. This initiative would create an efficient, environmentally friendly, and sustainable waste management system.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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